Influence of Natural Aggregates' Mineralogical Composition on the Adhesiveness and Affinity of Bitumen

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Abstract The paper presents the studies and the laboratory researches performed on two important factors that influence the durability of the asphalt mixture, namely the adhesiveness and affinity of bitumen to aggregates. To highlight the two characteristics, one bitumen grade (50/70) and natural quarry aggregates from five different sources were used. The experimental program consisted of determining the adhesiveness through the qualitative method (spectrophotometric method, nondestructive method) and the affinity through the rolling bottles method (destructive method), the main purpose of this study being to draw the attention to a possible link between these two methods. The results obtained vary from one aggregate source to another given the morphology and the physical-chemical properties of the aggregates. The research findings complete the picture of the factors that influence the adhesiveness and affinity of bitumen to aggregates and highlight the susceptibility to the stripping of binder under the humidity effect of the aggregate-binder bond.

Keywords Bitumen · Adhesiveness · Affinity · Aggregates

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H. Di Benedetto et al. (eds.), *Proceedings of the RILEM International Symposium on Bituminous Materials*, RILEM Bookseries 27,
https://doi.org/10.1007/978-3-030-46455-4_139

1 Introduction

The adhesiveness of the bitumen towards natural aggregates is a basic characteristic that affects the durability and the operation performances of the asphalt mixtures [1–3].

The main factors influencing the adhesiveness are the type and nature of the natural aggregates, as well as the bitumen type. The natural aggregates should come from homogenous rocks, with no degradation, freezing-thawing resistant and without foreign elements. The presence of water on the bitumen-aggregate interface may lead to adhesiveness loss through different stripping [4, 5].

In order to emphasize the two characteristics (adhesiveness and affinity), a single type of bitumen (50/70) and quarry natural aggregates from five sources were used.

2 Materials

2.1 Natural Aggregates

The natural aggregates used in the research were 4–8 size chippings, from five different natural stone quarries in Romania (Table 1, Figs. 1, and 2. All the sources of aggregates involved in the research were subjected to the mechanical resistance testing (Micro Deval wearing test). All the other data concerning the physical-chemical characteristics were considered taking into account the nature of the aggregates.

Table 1 Natural aggregates used: sources, rock nature and chemical composition

Stone quarries	Counties	Rock nature	Chemical composition
Patars	Arad (AR)	Basalt	Basic
Morlaca	Cluj (CJ)	Dacite	Acidic
Hauzesti	Timis (TM)	Diorite	Neutral
Poiana Ilvei	Bistrita-Nasaud (BN)	Andesite	Acidic
Forotic	Caras-Severin (CS)	Diorite	Neutral

Fig. 1 Aggregate used 6 mm in size

Fig. 2 Natural aggregate used: source location

2.2 Bituminous Binders

The bitumen used in the research was road bitumen penetration 50/70, provided by a Hungarian company. The product has the following characteristics shown by laboratory tests (Table 2).

Table 2 Characteristics of the used bitumen

Characteristic	U.M	Values
Penetration at 25 °C	0.1 mm	54
Softening point	°C	48.6
Ductility	Cm	>150
Mass variation	%	0.04
Increase of softening point after RTFOT	°C	6.78
Residual penetration	%	5.5
Ductility after RTFOT	Cm	>150

3 Results and Methodology

3.1 Adhesiveness

The adhesiveness of the road bitumen to the natural aggregates coming from the five different quarry sources was determined through spectrophotometry. The principle of the method consists in determining the adhesiveness of the bitumen to the natural aggregate, calculated through the absorption of a dyestuff from a solution of given concentration by the natural aggregate as such and by the filmed aggregate (the dyestuff not absorbed by the bitumen).

The results of the adhesiveness tests performed during the present study (Fig. 3) emphasize the following aspects.

The 50/70 road bitumen shows an improved adhesiveness to the aggregates coming from the sources „Patars" (AR), „Poiana Ilvei" (BN) and „Forotic" (CS), the obtained values being adequate (min. 80%) even in the case of non-added bitumen. Conversely, its adhesiveness to aggregates coming from the sources „Morlaca" (CJ) and „Hauzesti" (TM) is unsatisfactory.

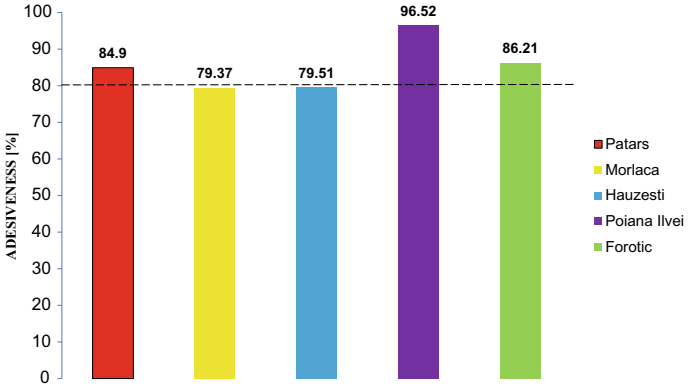

Fig. 3 Adhesiveness values

The chemical composition of the three sources with suitable adhesiveness (min. 80%) differs, it is therefore estimated that the superior adhesiveness values of these three aggregate sources is due to the petrographic nature of the aggregates or the shape of the chipping grains.

According to the visual analysis of the used chipping grain shape, the rounder aggregates (Morlaca and Hauzesti) show a higher adhesiveness to bitumen.

This study confirms the importance of the grain shape for the behavior of asphalt mixtures.

The aggregates coming from different sources but having the same chemical composition (Morlaca and Poiana Ilvei) subjected to another crushing process present a significantly different behavior.

The shape of the grains and the quantity of silicon dioxide (SiO_2) impact more on the adhesiveness than the origin of the aggregates (only in the case of the studies aggregates).

The non-coated aggregates with neuter chemical composition (that is the silicon dioxide content between 52 and 65%) present a higher concentration of the coloring solution, following the performance of the adhesiveness test.

The coated aggregates from the five sources show a roughly uniform concentration of the coloring solution, all the concentrations following the value 0.8×10^{-3}.

The variation of the concentrations results from the degree of bitumen covering of the aggregates used in the test, this degree is influenced by the temperature, luminosity inside the laboratory and the awareness of the user during the coating.

The test showed that a good mechanical grip realized on a hard aggregate is more important than the mineralogical composition of the aggregates for the preservation of the adhesiveness between bitumen and aggregates [6, 7].

It has been noted that in the case the aggregates are covered with a thin layer of water or dust, the bitumen can cover the aggregate grains but it cannot adhere to their surface [8].

The thin water/dust layer prevents the realization of the contact between the bitumen and the surface of the aggregates [9].

3.2 Affinity

The affinity of the aggregate to the bitumen was determined as the visual degree of covering with bitumen of the grains in the non-hardened asphalt mixture subjected to the procedure of water mixing of bottles rolled during a given time.

The results of the laboratory tests (Fig. 4) performed on the affinity between bitumen and natural aggregates emphasize the following main aspects.

The affinity of the used 50/70 bitumen to the aggregates from the source „Forotic" (CS) is higher than the one from the other sources of aggregates.

The lowest affinity values were obtained on the aggregates from the sources „Patars" (AR) and „Hauzesti" (TM), the aggregates from the source „Hauzesti" (TM) presented also a lower adhesiveness than the minimum stipulated by AND

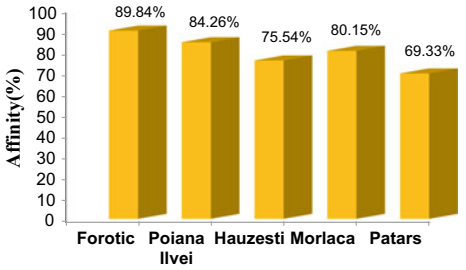

Fig. 4 Affinity values

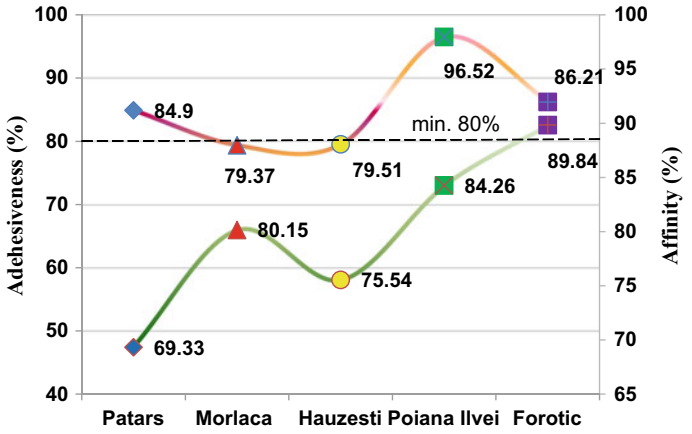

Fig. 5 Adhesiveness—affinity comparison

605. This was not the case for the aggregates from the „Patars" source, since in this case the adhesiveness value was higher than the minimum one (Fig. 5).

4 Conclusions

The adhesiveness between the bitumen and the natural aggregates is determined by mechanical factors, the humidity degree and dust content of the aggregates, the micro-texture of the aggregates, the grading of the mineral mix and the physical and chemical nature of the aggregates (acid, base and neuter).

The tests showed that a good mechanical link, realized on a hard aggregate, is much more important than the mineralogical composition of the aggregates for maintaining the adhesiveness between the bitumen and the aggregates.

The affinity test takes 6, 24, 48 and 72 h, but the results begin to be relevant only after 24.

The results emphasize the fact that the affinity is directly proportional to the wearing resistance of the aggregates (a value of the wearing resistance ranging in the quality/screening conditions stipulated by AND 605 specific to each technical class of road, leads to an adequate affinity value). In this regard, the conclusion resulting from this comparison is that the wearing resistance of the aggregates influences the affinity and its value depends on the mechanical characteristics of the aggregates used when manufacturing of the asphalt mixture.

In order to increase the values of the affinity and the adhesiveness of the bitumen to the natural aggregates where the minimum values are reached, chemical additives or the use of polymer modified bitumens are needed to increase these characteristics.

References

1. Li, Y., Yang, J., Tan, T.: Study on adhesion between asphalt binders and aggregate minerals under ambient conditions using particle modified atomic force microscope probes. Const. Build. Mater. 159–165 (2015)
2. Valdès, G., MirÒ, R., Martinez, A., Calabi, A.: Effect of the physical properties of aggregates on aggregate-asphalt bond measured using UCL method. Constr. Build. Mater. **73**, 399–406 (2014)
3. Pop, M., Ciont, N., Iliescu, M.: Assessing the influence of different additives on the recycling capabilities of asphalt mixtures. In: 16th International Multidisciplinary Scientific Conference SGEM, Book, (2016)
4. AND 605, Romanian Standard: Mixturi asfaltice executate la cald. Conditii tehnice privind proiectarea, prepararea si punerea in opera. AND 605 (Hot asphalt mixes. Technical conditions concerning the design, manufacturing and laying) (2016)
5. EN 12697-11: Bituminous mixtures. Test methods for hot mix asphalt. Part 11. Determination of the affinity between aggregate and bitumen (2012)
6. Fischer, H.R., Dilingh, E.C., Hermese, C.G.M.: On the interfacial interaction between bituminous binders and mineral surfaces as present in asphalt mixtures. Appl. Surf. Sci. **265**, 495–499 (2013)
7. Krzysztof, B., Jacek, O., Hubert, P., Marta, W.W.: Testing of bitumen-aggregate affinity by various methods. In: 6th Euroasphalt & Eurobitume Congress, Prague (2016)
8. Porot, L., Besamusca, J., Soenen, H., Apaegyei, A., Grenfell, J., Sybiliski, D.: Bitumen/Aggregate affinity rilem round robin test of rolling bottle test. In: 8th Rilem International Symposium on Testing and Characterization of Sustainable and Innovative Bituminous Materials, RILEM Bookseries 11 (2018)
9. Bagampadde, U., Isasccon, I.: Impact of bitumen and aggregate composition on stripping in bituminous mixtures. Mater. Struct. **39**, 303–315 (2006)